Fig. 8. View of the integuments at the micropyle as seen in the longitudinal median section of the corn. × 325.

Fig. 9. Transverse section of coats, etc., in the middle region of the ovule of the corn. The line of compacting in the ovary wall has formed, the innermost cells are freed, the inner integument is compressed, the epidermis of the nucellus remains. × 325.

PLATE XXVI.—Fig. 10. Transverse section of the coats of the corn grain at maturity after treatment with cold potassic hydrate. × 400.

Fig. 11. Transverse section through the coats of the mature oat grain showing the union of the remaining cells of the ovary wall with the inner integument. The layer to the left of *i* is the inner integument; to the right, the epidermis of the nucellus × 465.

Fig. 12. Transverse section of the inner coverings of the mature wheat grain, showing union of the chlorophyll cells of the ovary wall with the inner integument after treatment with KOH. × 735.

Fig. 13. Transverse section of the coverings of the mature wheat grain. × 465.

Contribution to the biology of the organism causing leguminous tubercles.

GEO. F. ATKINSON.

WITH PLATES XII–XV.

[Continued from p. 166.]

Historical resume.

Early period of investigations.

The tubercles were at first supposed to be normal parts of the plants on which they were found. According to Vuillemin[6], De Léchamp[7] named the genus *Ornithopus* from the character of the tubercles and De Candolle[8] uses the form of the tubercles as one of the characters of a variety of *Ornithopus perpusillus*.

Bivona[9] took them to be fungi of the genus *Sclerotium* and distinguished two types, the simple ones as *S. lotorum* and the lobed ones as *S. medicaginum*. Persoon's *Sclerotium rhizogonum*[10] was also founded upon certain of these tubercles. Fries[11] rejects Persoon's *S. rhizogonum* referring the forms on

---

[6]Les tubercles radicaux des Légumineuses. Ann. d. Sci. Agronom. franç. et etrang. 1888. p. 96.

[7]Histoire générale des plantes. 1615.

[8]Prodromus Syst. Nat. Reg. Veg. II (1825). 312.

[9]Pugill. plant. rar., Siculæ, IV. 26.

[10]Traité sur les champignons comestibles, Paris. 1818.

[11]Systema Mycologicæ, II. 250.

which it was based to growths from the roots of *Vicia*, etc. Fries however retains Bivona's two species *S. lotorum* and *S. medicaginum* and it was reserved for Tulasne[12] to cast them out of the category of fungi. To A. P. DeCandolle[13] they resembled small fungi like *Sclerotium* but he regarded them as diseased outgrowths and Wigand[14] recently has looked upon them as pathological forms.

Jessen[15] doubts their parasitic origin, and Clos[16] believed them normal structures with a physiological role and called them lenticels.

Others saw in them the products of animal parasitism, Malpighi[17] giving to insects the credit of their origin while Cornu[18] preferred to charge them to the account of *Anguillulidæ*. Later he withdrew the charge and treated them as root branches.[19]

Those who have argued that the tubercles were normal organs of the Leguminosæ hold very diverse views as to their function in the plant economy. Gasparini[20] describes them as swollen lateral roots and with Kolaczek[21] thought they were organs for absorbing food. DeVries[22] and Wittmack[23] interpreted them as lateral roots with dwarfed growth, while Treviranus[24] judged they were imperfect buds which in case

[12] Fungi Hypogaei. 1851.

[13] Mémoire sur les Légumineuses. 1825.

[14] Bakterien innerhalb der geschlossenen gewebes der knollenartigen Anschwellungen der Papilionaceen Wurzel. Bot. heft. Forsch. aus dem Bot. Gart. Z. Marburg, 1887, p. 88, cited by Pichi, Atti della Società Toscani di scienze naturali, 1888.

[15] Sitzungsbericht d. Bot. Verein d. Prov. Brandenburg, 1878. p. 54.

[16] Ebauche de la rhizotaxie, 1848; Du collet dans les plantes et de la nature de quelques tubercles. Ann. d. Sci. Nat. Bot. III. XIII. 1849.

[17] Anatome Plantarum pars sec. de Gallis. Opera I. 1687, cited by Vuillemin, l. c. See also Sorauer, Pflanzenkrankheiten. I. 744; Frank, Krankheiten der Pflanren.

[18] Commission du Phylloxéra. 1876.

[19] Etudes sur le Phylloxera vastatrix. Memoires de l' Académie des sciences. XXVI. 1878.

[20] Osservazioni sulla struttura dei spongiolari di alcune piante leguminose, Lette all. Ac. di Napoli, 1851; cited by Tschirch, Ber. d. deutsch. bot. Gesells. V (1887). 58.

[21] Lehrbuch der Botanik, 1856. p. 374.

[22] Wachstumsgeschichte des roten Klees. Landw. Jahrb. von Theil 6, 1, 1877; Verhandlung d. Bot. Vereins d. Prov. Brandenburg. 1878. p. 54–55.

[23] Verhandlung d. Bot. Vereins d. Prov. Brandenburg. 1874. p. 54.

[24] Ueber die Neigung der Hülsengewächse zu unterirdischer Knollenbildung. Bot. Zeit. 1853, p. 393. See Vuillemin.

the plants did not fruit could themselves develop into perfect plants. According to Nobbe,[25] Lachman,[26] Mattirolo e Buscalioni[27] they were places for the storage of reserve food materials.

These notions were probably empirical and derived more from superficial examination than from any serious attempt at an anatomical study of their structure and contents.

Middle period of investigations.

The period of serious investigation into their structure and etiology begins with Woronin's[28] contribution in 1866. He described the tubercles as being composed mainly of a parenchymatous tissue which is separated into an inner central mass and an outer layer, the two portions being separated by a layer of fibro-vascular tissue which arises from corresponding tissue in the central cylinder of the root. The inner parenchyma he described as possessing turbid contents while the outer was clear. The growing point or meristem of the tubercle lies in the distal portion of the inner parenchyma, the proximal portion being occupied by bacteria-like bodies or vibrios which filled the plasmic substance. These he considered to be the cause of the tubercles.

The next important contribution was by Eriksson[29] who distinguished what he supposed were two organisms in the tubercles. One he verified as the vibrio-like bodies discovered by Woronin which occupy the proximal portion of the central parenchymatous tissue. In the distal portion of the central parenchymatous tissue he discovered what he took to be fungus strands lying in a radial position, branching into finer threads as they approached the center. He described

---

[25] Vegetationsversuche in Boden mit lokalisirten Nährstoffen. Landwirtschaftliche Versuchstationen, 1868, p. 98.

[26] Ueber Knollchen der Leguminosen. Landw. Mittheil. Zeitschr. d. k. Lehranstalt und Versuchstationen, Poppelsdorf, 1856, p. 37. Cited by Tschirch, l. c.

[27] Si Contengono bacteri nei tubercoli radicati delle Leguminose? Malpighia I, *21*, 464, cited by Pichi, l. c.

[28] Ueber die bei der Schwarzerle und der gewœhnlichen Garten-Lupine auftretenden Wurzelanschwellungen, Mem. d. l' Acad. Imp. d. Sciences, VII. x (1866) 2.

[29] Studier öfver Leguminosernasrotknölar, Lund, 1874; Bot. Zeitung, 1874 p. 381. Cited by Vuillemin, l. c. and others

also the characteristic enlargements of these structures where they pass through the cell walls. He believed these fungus hyphæ to be the real cause of the tubercles.

DeVries[30] observed the hyphæ described by Eriksson but did not believe they stood in causal relation to the tubercles.

Schindler[31] also detected the hyphæ but claimed they enter after the tubercles begin to degenerate, while Cornu[32] and Mattei[33] declare there exists no mycelium in the tissues.

Kny[34] recognizes the presence of strands but denies the presence of a membrane. He believed they were strands of a plasmodium similar to Woronin's *Plasmodiophora brassicæ*[35] and about this time Woronin[36] retreats from his former position that the tubercles were caused by bacteria or vibrio-like bodies, and believes them to be due to a plasmodium, being influenced probably by his studies upon the club-foot of cabbage.[37] Prillieux[38] largely corroborated the studies of Eriksson, especially in regard to the structure of the tubercles and their parasitic origin, but believed them to be caused by a plasmodium, related to Woronin's *Plasmodiophora brassicæ*, which excretes a viscid substance.[39]

In 1879[40] appeared B. Frank's first important paper on the subject. He found both the hyphæ and the bacteria-like bodies. He believed the latter sprouted off from the former. In an earlier publication[41] he thought the fungus to be closely allied

---

[30] Wachstumsgeschihcte des roten Klees. Landw. Jahrb. 1877.

[31] Ueber die biologische Bedeutung der Wurzelknœllchen bei den Papilionaceen. Jour. f. Landw. XXXIII, (1885), 325–336. Ueber die Bedeutung der sog. Wurzelknœllchen bei den Papilionaceen. Œsterreich. landw. Wochenblatt 22 (1885), n. 34, cited by Tschirch, l. c. Zur Kenntniss der Wurzelknœlchen der Papilionaceen. Bot. Centralb. XVIII (1884), 86.

[32] Mem. d. l' Acad. d. Sciences, XXVI (1878).

[33] Ancora sull. origine della Vicia faba. Bologna, 1887, cited by Vuillemin, l. c.

[34] Verhandlung. d. Bot. Vereins der Prov. Brandenburg, 1877. Ueber die Wurzelanschwellungen der Leguminosen und ihre Erzeugung durch Einfluss von Parasiten. Ibid. 1878.

[35] Pringsheim's Jahrb. f. wiss. Bot. XI, 548.

[36] Ibid., p. 371.

[37] Ibid., p. 548.

[38] Sur la nature et sur la cause de la formation des tubercles qui naissent sur les racines des Légumineuses. Bull. Soc. Bot. d. France, 1879, p. 98.

[39] Comptes Rendus d. sc. Paris, CXI, 926.

[40] Ueber die Parasiten in den Wurzelanschwellungen der Papilionaceen. Bot. Zeitung. XXXVII (1879), n. 24, 25.

[41] Lemmis: Synopsis: Kryptogamen, p. 1,944.

to the genus Protomyces of De Bary,[42] but now he transfers it to the genus *Schinzia* founded by Nægeli[43] on a fungus which causes galls on the roots of *Cyperus*, and calls it *Schinzia leguminosarum*, thus considering it to be closely related to the fungus in galls on the roots of Alnus first described by Woronin.[44] It is quite important in view of Frank's change of opinion at a subsequent date to note that an examination of the illustrations and descriptions which accompany this paper leaves no doubt that at that time he considered the bacteria-like bodies to be budded off from the hyphæ though he did not actually see the budding take place. This paper of Frank's brought out a rejoinder from Kny[45] who states that the bacteria-like bodies are the spores of the plasmodium.

The general effect of these investigations was to give a feeling of confidence in the view that the etiology of the tubercles was primarily due to the irritating or stimulating influence of some organism in the soil, though there was great diversity of opinion as to the character of the organism.

This feeling of confidence, however was soon shaken by the appearance in 1885 of a paper by Brunchorst.[46] Brunchorst claims that the tubercles are not caused by any organism. He affirms the older views that they are normal structures. To the vibrio-like bodies he ascribes an entirely new role. He believes them to be differentiated portions of the plasmic protein contents of the cells. While they possess the form of bacteria they are inert and serve as receptacles for the storage of proteid substance by the plant since they were found to be exceedingly rich in protein matter and that later their contents are absorbed by the plant. Because of their morphological resemblance to bacteria Brunchorst termed them bacteroids. He observed the fungus hyphæ but did not consider them to stand in causal relation to the tubercles since he found none

---

[42] Beiträge zur Morph. u. Phys. d. Pilze, I.

[43] Sur des Champignons vivant dans l' interieur des cellules végétales. Linnæa, 1842, p. 278. Translated in Ann. Sci. Nat. Bot. II, XIX (1843), 86.

[44] Observations sur certaines excroissances que presentant les racines d. l'aune et d. lupin des jardin. Ann. d. Sci. Nat. Bot. V. VII, 73. See also footnote 28

[45] Zu dem Aufsatze des Herrn Prof. B. Frank über Parasiten in den Wurzelanschwellungen der Papilionaceen. Bot. Zeit. 1879. p. 537.

[46] Ueber die Knœllchen an den Leguminosenwurzeln. Ber. d. Deutsch. Bot. Gsells. III (1885). 241-257.

in the tubercles of lupines. He as well as Eriksson[47] showed that two types of structure existed, one represented by the tubercles on lupine, and the other by those on peas, etc.

Schindler,[48] Tschirch,[49] Benecke,[50] Van Tieghem and Duliot,[51] and Sorauer[52] supported Brunchorst's view. Tschirch even went farther and considered the fungus hyphæ to represent nothing but preliminary stages in the differentiation of the cell plasma into bacteroids. Lecomte[53] considered that both the hyphæ and bacteroids were receptacles for the storage of albuminous material. Tschirch[54] calls the tissue in which the bacteroids are found "bacteroid tissue."

B. Frank[55] now unreservedly abandons his earlier views of the parasitic origin of the tubercles and holds it proved by Brunchorst that they represent peculiar organs of the Leguminosæ for the storage of proteid substance. He ascribes to the galls on Alnus, Elæagnus, etc., a similar role, while Brunchorst about this time in a preliminary paper[56] and later in a full presentation of his work on Alnus galls finds them to be due to a fungus.[57]

Thus the question hung, as it were, in the balance at the close of what might be termed the middle period of investigations on this subject. But important contributions were soon to be published which would remove all doubt of the causal relationship of the soil organisms to the tubercles.

---

[47] Studier œfver Leguminosernas rotknœlar. Lund. 1874. Bot. Zeit. xxxv (1874). 381.

[48] Ueber die biologische Bedeutung der Wurzelknœllchen bei den Papilionaceen. Jour. Landw. xxxiii (1885).

[49] Ueber die Wurzelknœllchen der Leguminosen. Gesells. Naturw. Freunde zu Berlin, and Bot. Centralb. xxxi (1887.)

[50] Ueber die Knœllchen an den Leguminosen-Wurzeln. Bot. Centralb. xxix (1887). 53.

[51] Origine, structure et nature morphologique des tubercles radicaux des Légumineuses. Bull. d. Soc. Bot. France. xxxv (1888).

[52] Zusammenstellung der neuern Arbeiten über die Wurzelknœllchen und deren als Bakterien angesprochene Inhaltskœrperchen, Bot. Centralb. xxxi (1887). 308.

[53] Bulletin d. l. Soc. Bot. d. France. 1888.

[54] Beitrœge zur Kenntniss der Wurzelknollchen der Leguminosen. Ber. d. Deutsch. Bot. Gesells. v (1887). 58.

[55] Sind die Wurzelanschwellungen der Erlen und Elæagnaceen Pilzgallen? Ber. d. Deutsch. Bot. Gesells. v (1887).

[56] Ueber die Knœllchen an den Wurzeln von Alnus und den Elæagnaceen. Bot. Centralb. (1880). 354.

[57] Ueber einige Wurzelanschwellungen, besonders diejenigen von Alnus und den Elæagnaceen. Unters. Bot. Inst. Tübingen. ii (1886). 151.

Recent period of investigation.

Ward[58] by a very careful series of inoculations with soil material proves conclusively that the tubercles are caused by some organism which is very abundant in the soil. Frank[59] had even earlier carried out similar experiments which pointed to like results. Ward traces the development of the fungus strands from infection in the root hairs, its growth down into the cortical parenchyma, and into the tissue of the tubercle, where it branches in all directions. He describes and figures the peculiar enlargements where the hyphæ pass through the cell walls, and also enlarged portions of the hyphæ within the cell lumen, characters which we have seen were noted by earlier observers.

On some of these enlarged portions he observed very small buds, or "gemmules," as he termed them, similar to those described by Frank. He considers these the points of origin of the bacteroids, in fact that the bacteroids, or gemmules, are budded off from the hyphæ. According to Ward these gemmules then increased by farther budding within the tubercle. Since there was some correspondence between this supposed development of the gemmules, or bacteroids, with the development of the sporids from the promycelia of some of the Ustilagineæ, and the successive buddings of the sporids in nutrient solutions, as shown by Brefeld,[60] Ward[61] believed the fungus of the tubercles to be related to the Ustilagineæ, but through its peculiar symbiotism with its host, by which the "gemmules" could be preserved through the summer period and then during winter and spring set free by the decay of the tubercles, there was not the need of resting spores such as are found in the known Ustilagineæ, and consequently they had ceased to be produced. About the same time the cultural researches of Hellriegel,[62] Hellriegel

---

[58]On the tubercular swellings on the roots of Vicia Faba. Phil. Trans. Royal Society. CLXXVIII (1887). 139–562.

[59]Bot. Zeitung, XXXVII. n. 24–25, 1879.

[60]Botanische Untersuchungen. v. Die Brandpilze I. 1883.

[61]See also, On the tubercles on the roots of leguminous plants with special reference to the pea and bean. Proceed. Royal Society. XLVI. 1889.

[62]Welche Stickstoffquellen stehen den Pflanzen zu Gebote? Tageblatt d. Naturf. Versamml. zu Berlin, 1886, p. 290.

and Wilfarth,[63] and Laws and Gilbert[64] confirmed the investigations of Ward, that the tubercles are due to the action of some organism within the soil.

Ward pointed out that the relation of the low organism to its host was that of a symbiosis, with mutual benefit. Lundstrœm[65] entertains similar views, but left it undetermined whether the lower symbiont was a plasmodium or one of the bacteria.

In 1888 a very important contribution to the biology of the organism was presented by Beyerinck.[66] He undertook the cultivation of the organism in artificial media and claims to have carefully studied the development and morphology of several races or varieties, and in the tubercles he thought he could trace the development of the bacteroids from bacteria. The organism he considers one of the bacteria, and names it *Bacilius radicicola*. Besides the rod forms he describes a motile form of the organism which is very much smaller. He rejected the idea of the presence of fungus hyphæ. These he considered to be the products of nuclear division. Not admitting a hypha as the means of infection he tried to explain the entrance of the organism and its passage from cell to cell by stating that there were invisible pores in the cell walls.

In 1888 Vuillemin[67] published his investigations, the results of which, while maintaining the relation of some symbiont in the tubercles, appear to be quite at variance with others concerning the nature of the organism. His studies of the development of the organism were directed to an examination of certain of the tubercles in the autumn. He observes the fungus threads and interprets the enlargements as sporangia. He claims to have observed the formation of zoospores in the sporangia. These he describes as pyriform, with a cilium at

[63] Untersuchungen über die Stickstoffnahrung der Gramineen und Leguminosen. Beilageheft z. d. Zeitschr. f. d. Rübenzucker Ind. d. D. R. Berlin, Nov. 1888. Review in Bot. Centralb. XXXIX (1889). 138.

[64] On the present question of the sources of the nitrogen of vegetation, etc. Phil. Trans. Royal Society, CLXXX. B. 1–107. Etat actuel de la question des sources d'azote de la vegetation. Ann. Agr. XIV (1888).

[65] Ueber symbiotische Bildungen bei den Pflanzen. Bot. Centralb. XXVIII (1886).

[66] Die Papilionaceenknœllchen, Bot. Zeit. 1888, p. 725–735, 741–750, 757–771, 780–790, 797–804.

[67] Les tubercles radicaux des Léguminenses, Ann. d. Sci. Agr. Franç. et Etrang. 1888, p. 96.

the smaller end. They conjugate by fusion and form cysts. The non-septate character of the hyphæ taken in conjunction with the formation of zoospores, would ally the fungus with the *Chytridiaceæ* and Vuillemin considered it to be an undescribed species of the genus *Cladochytrium*, and called it *Cl. tuberculorum*. A comparison with Nowakowski's description and figures of *Cladochytrium tenue*[68] shows at least a striking resemblance in the form of the fungus as the hyphæ ramify through the tissues of *Acorus*, presenting here and there intercalary and terminal sporangia.

Vuillemin, with Ward,[69] Lundstrom[70] and Schindler,[71] believes a symbiosis to exist between the fungus and the Leguminosæ. While Lundstrœm classes the tubercles in the category of organs which are the products of mutual association, called by him "domatien,"[72] Vuillemin[73] prefers the name suggested by Frank[74] and calls them "*Mycorhizes endotrophiques*," or "*endomycorhizes*." Ward[75] shows that their inclusion among the Mycorhizæ is as logical as that of Frank's inclusion[76] of Warlich's[77] orchid root fungus.

Frank later[78] distinctly places them, as well as the galls, on Alnus, Elæagnus, etc., among his Mycorhizæ.

---

[68] Beitrag zur Kenntniss der Chytridiaceen. In Beiträge zur Biologie der Pflanzen, II (1876). 73-121.

[69] Phil. Trans. Royal Society, CLXXVIII (1887). 539–562.

[70] Ueber symbiotische Bildungen bei den Pflanzen, Bot. Centralb. XXVIII (1886).

[71] Zur Kenntniss der Wurzelknœllchen der Papilionaceen, Bot. Centralb. XVIII (1884). 86.

[72] Ueber Mycodomatien in den Wurzeln der Papilionaceen, Bot. Centralb. XXXIII, 1888.

[73] Remarques sur le memoire de Lundstrœm. Jour. de Botanique, April, 1888.

[74] Ueber die auf Wurzelsymbiose beruhende Ernährung gewisser Bäume durch unterirdische Pilze. Ber. d. deutsch. bot. Gesells. III (1885). 128-144. Neue Mittheihungen über die Mykorhiza der Bäume und der Monotropa hypopitys. Ber. d. deutsch. bot. Gesells. III (1885).

[75] Some recent publications bearing on the question of the sources of nitrogen in plants. Annals of Botany, I. (1887–1888). 325–357.

[76] Ueber neue Mykorhiza-Formen, Ber. d. deutsch. bot. Gesells. V (1887). 395–408.

[77] Beitrag zur Kenntniss der Orchideenwurzelpilze. Bot. Zeitung. XLIV (1886).

[78] Ueber die auf Verdauung von Pilzen abzielende Symbiose der mit endotrophen Mykorhizen begabten Pflanzen, sowie der Leguminosen und Erlen. Ber. d. deutsch. bot. Gesells. IX (1891). 244-253.

Following close upon Vuillemin's contribution were several by A. Prazmowski, a preliminary paper in 1888,[79] in which he considers the tubercles to be due to a parasitic fungus related to Woronin's *Plasmodiophora brassicæ.*

A second paper appeared in 1889,[80] and the final results of his study of the etiology and development of the tubercles was published in 1890.[81] Prazmowski now believes the tubercles to be due to one of the bacteria and he describes the organism obtained by himself in artficial cultures from the tubercles. By inoculation with the same he succeeded in developing the tubercles. According to him it is a bacterium. In artificial cultures it always develops in the form of simple short rods, which may for a time remain joined in short chains, but it never forms filaments. The rods may farther divide up into short cells, and it possesses a motile form. He denies the presence of fungus hyphæ, regarding them as gelatinous tubes which the organisms excrete to form a protective covering for the mass. The manner of infection through the root hairs agrees in all essential respects with that described by Ward (l. c.), only Prozmowski does not look upon the tube as having any genetic connection with the organism, but simply encloses them while the colony of bacteria directed by a common purpose move along together with the advancing tube down into the tissue of the root. In regard to this unity of purpose exhibited by the colony as described by Prazmowski, his organism would show a relationship to Thaxter's *Myxobacteriaceæ.*[82]

Prazmowski was unable to demonstrate the membranous nature of the tube, while there seems to be pretty good evidence from the experience of Eriksson,[83] Ward,[84] Vuille-

---

[79] Ueber Wurzelknœllchen der Leguminosen, Bot. Centralb. xxxvi (1886). 215-219, 248-255, 280-285.

[80] O istocie i znaczeuiu korzeniowych grochu. Berichte aus d. Sitz. d. k. k. Akad. d. Wissensch. in Krakau, June, 1889. Das Wesen und die biologische Bedeutung der Wurzelknollchen der Erbse. Bot. Centralb. xxxix (1889). 356-362.

[81] Die Wurzelknollchen der Erbse; Erster Theil, Die Ætiologie und Entwicklungsgeschichte der Knollchen. Landw. Versuchs-Stationen. xxxvii (1890). 160-236.

[82] On the Myxobacteriaceæ, a new order of Schizomycetes. Bot. Gazette, xvii (1892). 12.

[83] Studier œfver Leguminosernas rotknœlar. Lund. 1874. Bot. Zeit. xxxv. (1874). 381.

[84] Phil. Trans. Royal Society. clxxviii. (1887). 539-562. Proceed. Royal Soc. xlvi (1889). 431-443.

min,[85] Pichi,[86] A. Koch,[87] and Laurent[88] that a membrane does exist.

Short communications by Delpino[89] and Mattei[90] about this time support the view that the tubercles are caused by bacteria.

In 1890[91] Frank appears with still another contribution. While he does not wholly return to his earlier convictions he retraces his steps far enough to once more champion the causal relation of some soil organism. This time he believes the organism to be micrococcoid and names it *Rhizobium leguminosarum.* He still recognizes the two form elements in the tubercles, the hypha-like strands and the bacteroids. The former he believes to be a homogeneous mixture of the cell protoplasm of the two symbionts, in which nothing is visible indicative of the nature of the *Rhizobium* or the protoplasm of the leguminous plant. This mixture he terms *mycoplasm.* Upon treatment with certain reagents the portion of the mycoplasm belonging to the host plant dissolves and sets the micrococci free. Frank also obtained his *Rhizobium* in artificial culture and produced the tubercles by inoculation with the same. The bacteroids he regarded as fragments of the mycoplasm, while in a more recent communication[92] he says they are hypertrophied forms of the *Rhizobium.*

In the same year Laurent published a preliminary paper[93] on this subject, followed in 1891[94] by a more complete exposition of his investigations. He also obtained the organism in artificial cultures and recognizes the genetic connection of the bacteroids and fungus strands, believing with Ward and the earlier tenets of Frank that the bacteroids are budded off

---

[85] Ann. d. Sci. Agr. Franç. et etrang. 1888. p. 96.

[86] Alcune osservazioni sui tubercoli radicali delle Leguminose. Atti della Società Toscani di science naturali. 1888.

[87] Zur Kenntniss der Fäden in den Wurzelknöllchen der Leguminoseen.

[88] Ann. d. l'Institut Pasteur. v. (1891). 105–139.

[89] Osservazioni sopra batteriocecidii e la sorgente l'azote in una piante Galega officinalis. Malpig. II. fasc. 9–10. (1889). Cited by Prazmowski.

[90] Ancora sull' origine della Vicia faba. Bologna. 1887. Cited by Vuillemin.

[91] Ueber die Pilzsymbiose der Leguminoseen. Berlin, 1890.

[92] Berichte d. deutsch. bot. Gesellsch. IX. (1891). 244–253.

[93] Sur le microbe des nodosités des Légumineuses. Compt. Rend d. Sc. Paris. 1890. pp. 754–756.

[94] Recherches sur les nodosités radicales. Ann. d. l'Inst. Pasteur. v. (1891). 105–139.

from the hyphæ. He treats of the organism as a yeast form, and while in his artificial cultures a large number of the individuals were rod-like, some presented an irregularly lobed form. These forms together with the development of the bacteroids from the hyphæ he judges separates the organism from the true *Schizomyceteæ*. He accepts Frank's name *Rhizobium leguminosarum*, but believing it to be related to Metschnikoff's *Pasteuria ramosa*,[95] he locates it in the *Pasteuriaceæ*.

During the last year an article on this subject has appeared from an American writer.[96] The original part of Schneider's paper deals with the morphology of the bacteroids of several leguminous species, the variations in form of the bacteroids alone seeming in the estimation of the author sufficient ground for the characterization of species, and several species and varieties are named. Schneider accepts Frank's generic name *Rhizobium*, but rejects his theory of a mycoplasm. He denies the genetic connection of the bacteroids with the hyphæ, and definitely rejects the idea of any causal relation of the fungus hyphæ to the tubercles. He observes fungus threads in the tubercles, but cannot differentiate them from fungus threads which he finds in other parts of the roots where there are no tubercles.

[*To be concluded.*]

Cornell University.

BRIEFER ARTICLES.

Two new plants from Washington.—Allium Hendersoni.—About a foot high: bulb white, ovate, 6–7 lines in diameter, finely but indistinctly reticulated: leaves 2, linear-oblong, attenuate, thickish, 4–6 inches long, as many lines broad: scape rather stout, much exceeding the leaves: umbels many-flowered, globose: spathe 3-parted; bracts ovate, acuminate, 6–8 lines in length: pedicels 8–10 lines long: segments of the perianth rhombic-ovate, acuminate, 3–4 lines long, purple, with light midrib: stamens exserted: ovary 6-crested: seeds dull black, compressed, obovate, 1½ lines in length.—Collected near Pull-

[95] Pasteuria ramosa, un représentant des bactéries a division longitudinale. Ann. d. l'Inst. Pasteur. II. (1888.) 165–170.

[96] Observations on some American Rhizobia. Bull. Torrey Bot. Club XIX. July, 1892.